Communication Receivers

Communication Receiver

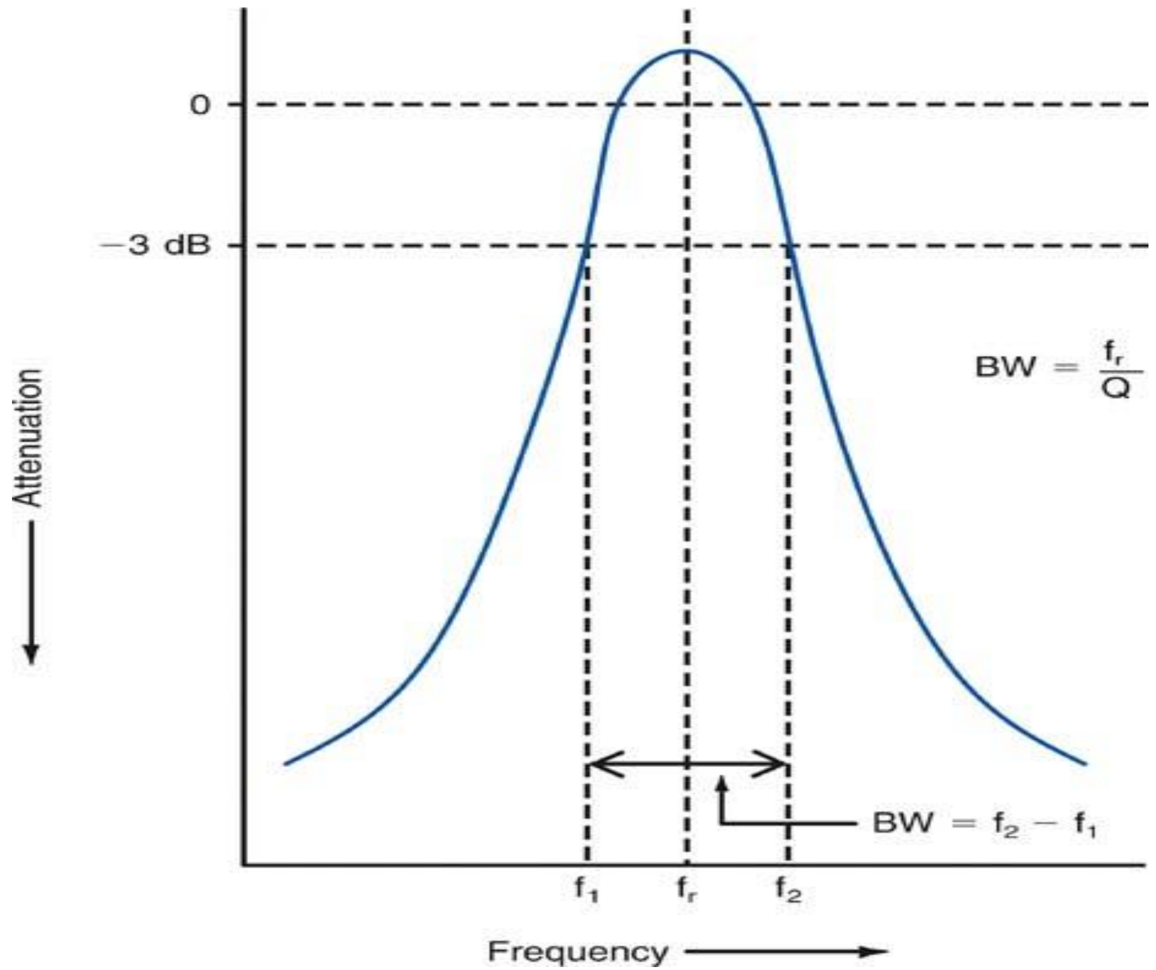
- In radio communication systems, the transmitted signal is very weak when it reaches the receiver, particularly when it has traveled over a long distance.
- The signal has also picked up noise of various kinds.
- Receivers must provide the sensitivity and selectivity that permit full recovery of the original signal.
- The radio receiver best suited to this task is known as the **superheterodyne receiver**.

Basic Principles of Signal Reproduction

- A communication receiver must be able to identify and select a desired signal from the thousands of others present in the frequency spectrum (**selectivity**) and to provide sufficient amplification to recover the modulating signal (**sensitivity**).
- A receiver with good selectivity will isolate the desired signal and greatly attenuate other signals.
- A receiver with good sensitivity involves high circuit gain.

Selectivity

- Selectivity in a receiver is obtained by using tuned circuits and/or filters.
- *LC* tuned circuits provide initial selectivity.
- Filters provide additional selectivity.
- By controlling the *Q* of a resonant circuit, you can set the desired selectivity.
- The optimum bandwidth is one that is wide enough to pass the signal and its sidebands but narrow enough to eliminate signals on adjacent frequencies.



Selectivity curve of a tuned circuit.

Sensitivity

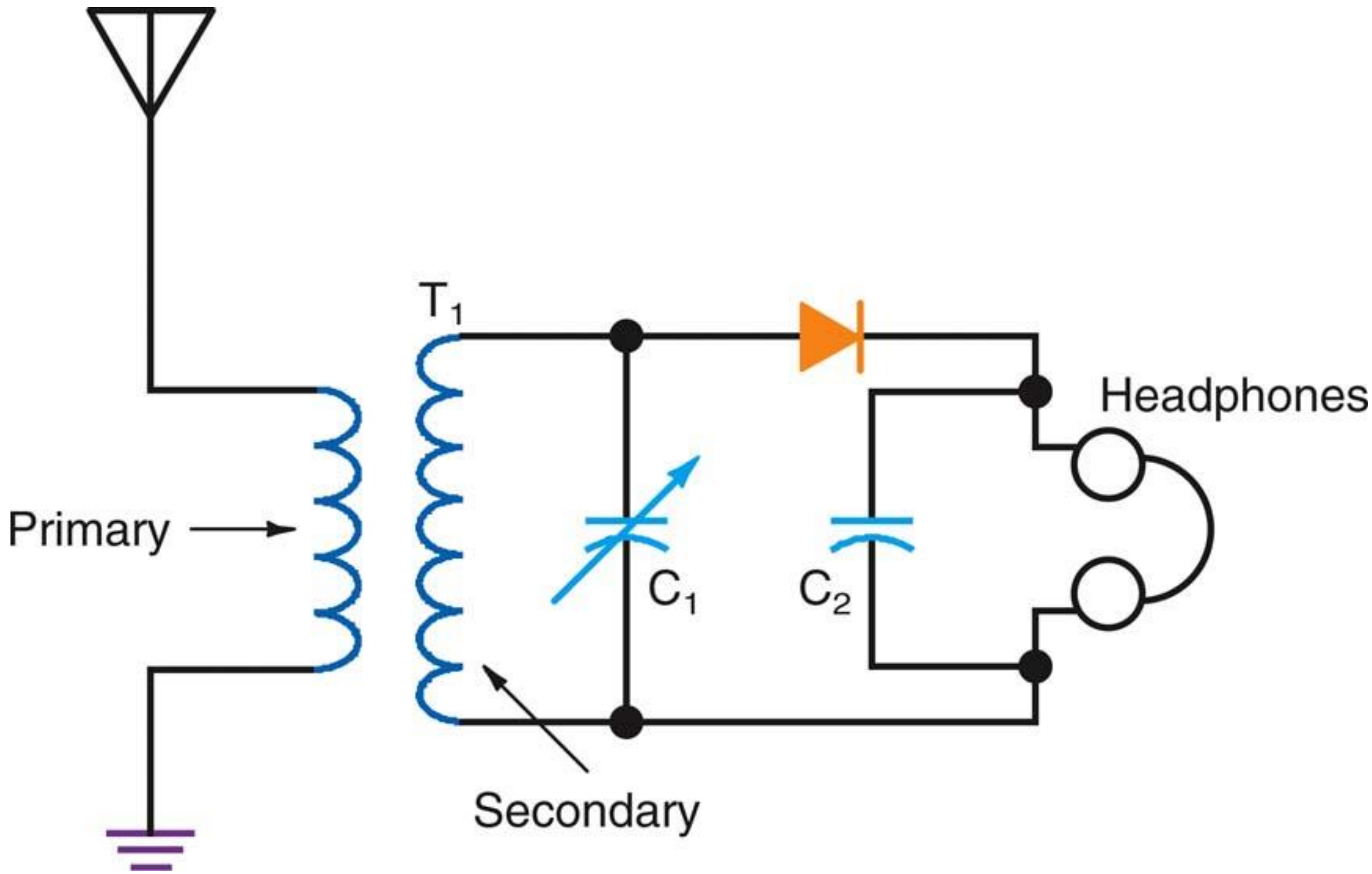
- A communication receiver's sensitivity, or ability to pick up weak signals, is a function of overall gain, the factor by which an input signal is multiplied to produce the output signal.
- The higher the gain of a receiver, the better its sensitivity.
- The more gain that a receiver has, the smaller the input signal necessary to produce a desired level of output.
- High gain in receivers is obtained by using multiple amplification stages.

Types of Receivers:

- Crystal Receiver
- Tuned Radio Frequency (TRF) Receiver
- Super-heterodyne Receivers

Crystal Receiver

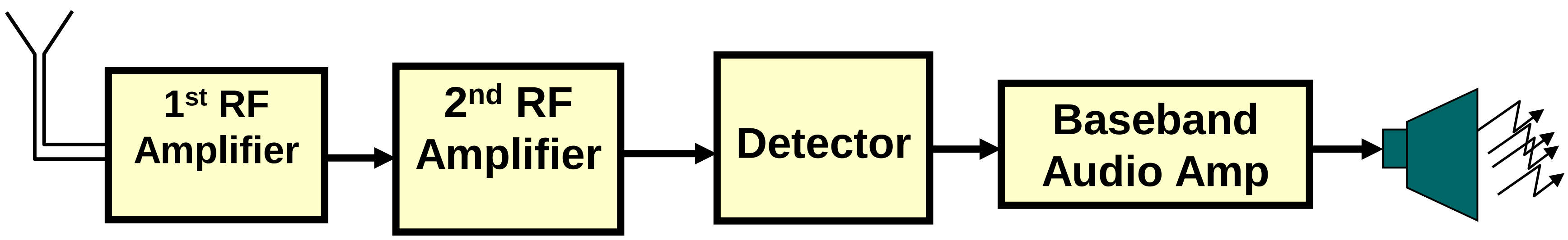
- The simplest radio receiver is a crystal set consisting of a tuned circuit, a diode (crystal) detector, and earphones.
- The tuned circuit provides the selectivity.
- The diode and a capacitor serve as an AM demodulator.
- The earphones reproduce the recovered audio signal.

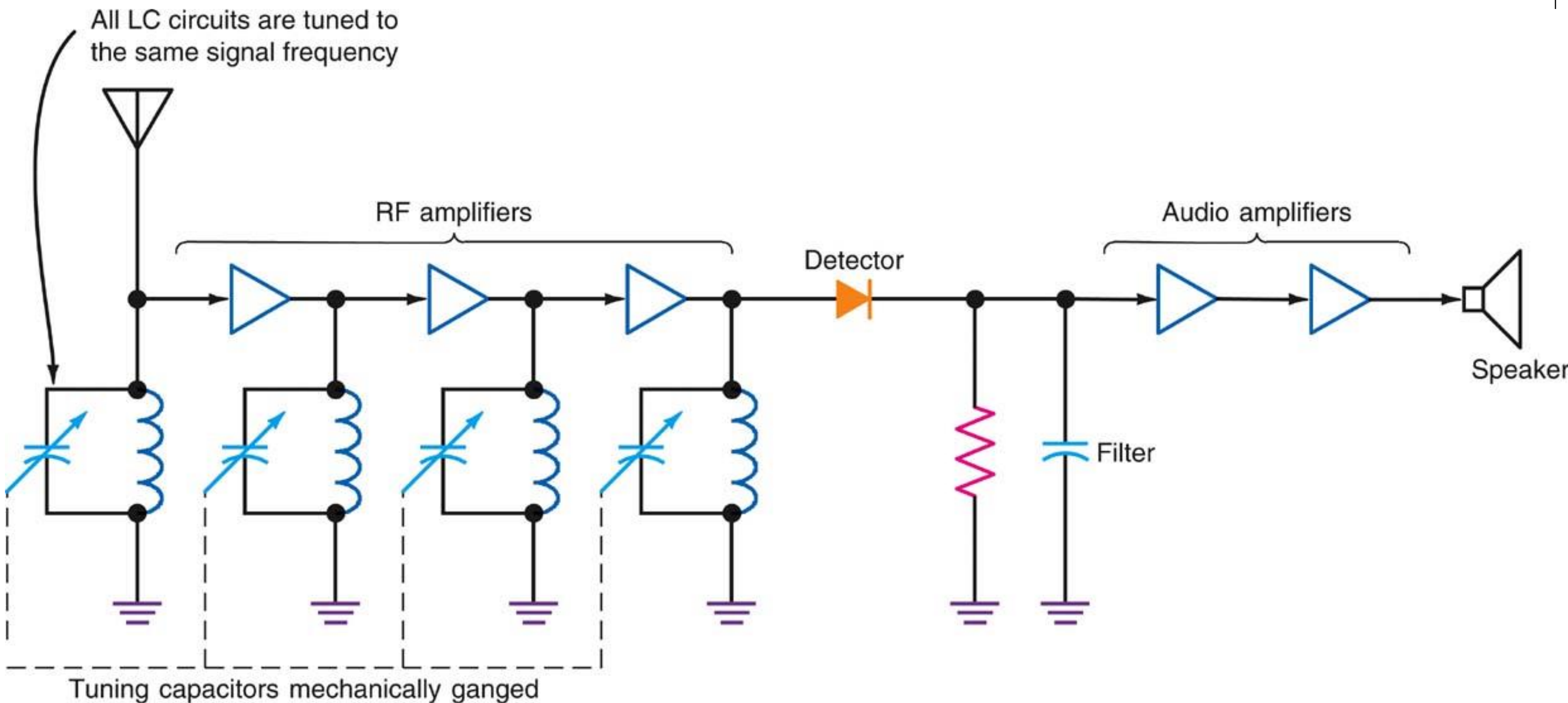


Crystal Receiver

Tuned Radio Frequency (TRF) Receiver

- In the tuned radio frequency (TRF) receiver sensitivity is improved by adding a number of stages of RF amplification between the antenna and detector, followed by stages of audio amplification.
- The RF amplifier stages increase the gain before it is applied to the detector.
- The recovered signal is amplified further by audio amplifiers, which provide sufficient gain to operate a loudspeaker.





Tuned radio-frequency (TRF) receiver.

Tuned Radio Frequency (TRF) Receiver

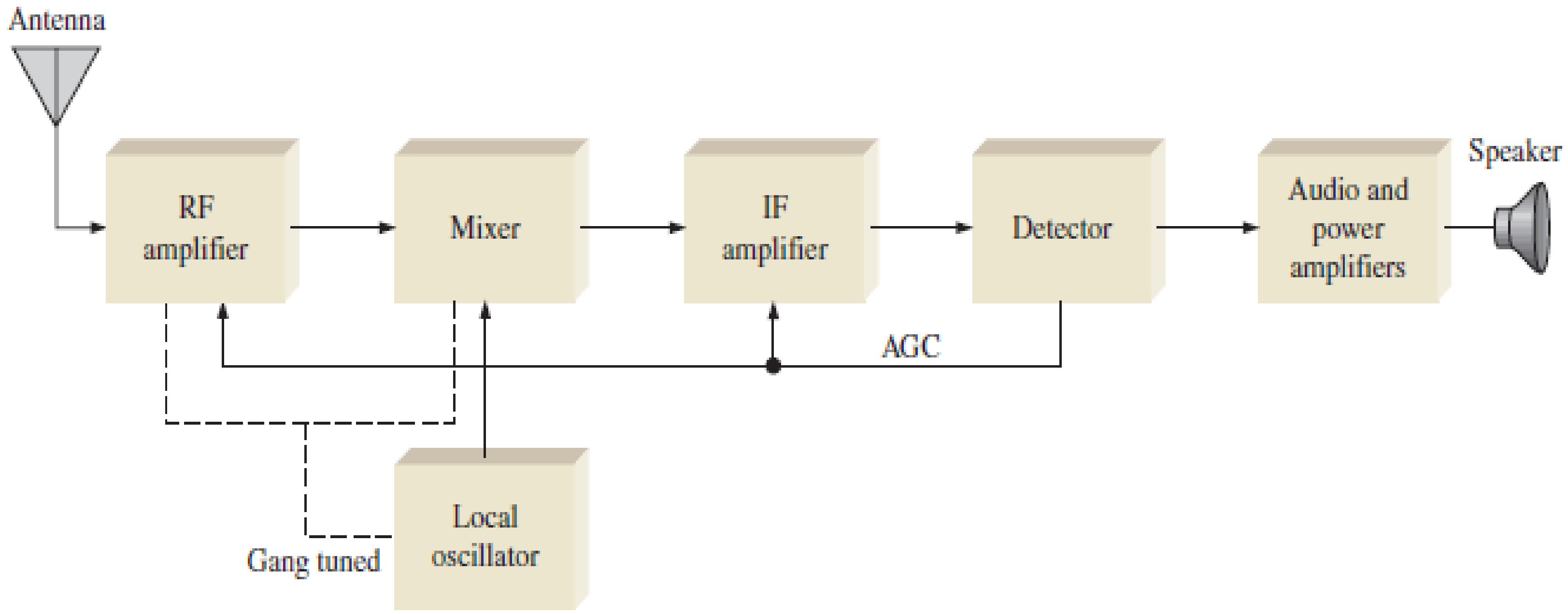
- Many RF amplifiers use multiple tuned circuits.
- Whenever resonant *LC* circuits tuned to the same frequency are cascaded, overall selectivity is improved.
- The greater the number of tuned stages cascaded, the narrower the bandwidth and the steeper the skirts.
- The main problem with TRF receivers is tracking the tuned circuits.
- In a receiver, the tuned circuits must be made variable so that they can be set to the frequency of the desired signal.
- Another problem with TRF receivers is that selectivity varies with frequency.

Super-heterodyne Receivers

- The hetero part refers to the translation to another frequency and the dynamis part refers to the apparent amplification of the detected signal during the heterodyne process
- Little progress in this receiver was made until Edwin Howard Armstrong in 1918 was able to develop the idea of using the frequency conversion of higher frequency signals down to the range of the then common heterodyne receiver.
- He was able to observe that the modulation on a signal did not alter during this frequency conversion process. The super part of super-heterodyne refers to super-sonic, meaning that the heterodyne process was extended above the audio frequency range.

Super-heterodyne Receivers

A block diagram of a superheterodyne AM receiver is shown in the Figure below. The receiver shown consists of an antenna, an RF (radio frequency) amplifier, a mixer, a local oscillator (LO), an IF (intermediate frequency) amplifier, a detector, an audio amplifier, a power amplifier, and a speaker.



Superheterodyne Receivers

- **Superheterodyne receivers** convert all incoming signals to a lower frequency, known as the **intermediate frequency (IF),** at which a single set of amplifiers is used to provide a fixed level of sensitivity and selectivity.
- Gain and selectivity are obtained in the IF amplifiers.
- The key circuit is the mixer, which acts like a simple amplitude modulator to produce sum and difference frequencies.
- The incoming signal is mixed with a local oscillator signal.

RF Amplifier

- The antenna picks up the weak radio signal and feeds it to the **RF amplifier**, also called a **low-noise amplifier (LNA).**
- RF amplifiers provide some initial gain and selectivity and are sometimes called **preselectors**.
- Tuned circuits help select the frequency range in which the signal resides.
- RF amplifiers minimize oscillator radiation.
- Bipolar and FETs can be used as RF amplifiers.

- ***Local Oscillator*** This circuit generates a steady sine wave at a frequency 455 kHz above the selected RF frequency.
- ***Mixer*** This circuit accepts two inputs, the amplitude modulated RF signal from the output of the RF amplifier (or the antenna when there is no RF amplifier) and the sinusoidal output of the local oscillator (LO). These two signals are then “mixed” by a nonlinear process called *heterodyning* to produce sum and difference frequencies. For example, if the RF carrier has a frequency of 1000 kHz, the LO frequency is 1455 kHz and the sum and difference frequencies out of the mixer are 2455 kHz and 455 kHz, respectively. The difference frequency is always 455 kHz no matter what the RF carrier frequency.

- ***IF Amplifier*** The input to the IF amplifier is the 455 kHz AM signal, a replica of the original AM carrier signal except that the frequency has been lowered to 455 kHz. The IF amplifier significantly increases the level of this signal. The advantage of the IF stage is that it can be designed for a single frequency, simplifying the receiver.

IF Amplifier

- IF must be such that the image response is rejected by RF amplifier.

up-side conversion

$$\boxed{f_{LO} = f_c + f_{IF}}$$

down-side conversion

$$\boxed{f_{LO} = f_c - f_{IF}}$$

- Image response: the same effect as that of the desired signal -> must be rejected!
- Image frequency: up-side conversion

$$\boxed{f_{image} = f_{LO} + f_{IF} = f_c + 2f_{IF}}$$

down-side conversion

$$\boxed{f_{image} = f_{LO} - f_{IF} = f_c - 2f_{IF}}$$

image rejection -> $\boxed{\Delta f_{RF} < 2f_{IF}}$

IF Amplifier

TABLE 4–4 SOME POPULAR IF FREQUENCIES IN THE UNITED STATES.

IF Frequency	Application
262.5 kHz	AM broadcast radios (in auto
455 kHz	AM broadcast radios
10.7 MHz	FM broadcast radios
21.4 MHz	FM two-way radios
30 MHz	Radar receivers
43.75 MHz (video carrier)	TV sets
60 MHz	Radar receivers
70 MHz	Satellite receivers

Demodulators

- The highly amplified IF signal is finally applied to the demodulator, which recovers the original modulating information.
- The demodulator may be a diode detector (for AM), a quadrature detector (for FM), or a product detector (for SSB).
- The output of the demodulator is then usually fed to an audio amplifier.

Automatic Gain Control

- The output of a demodulator is usually the original modulating signal, the amplitude of which is directly proportional to the amplitude of the received signal.
- The recovered signal, which is usually ac, is rectified and filtered into a dc voltage by a circuit known as the **automatic gain control (AGC)** circuit.
- This dc voltage is fed back to the IF amplifiers, and sometimes the RF amplifier, to control receiver gain.
- AGC circuits help maintain a constant output level over a wide range of RF input signal levels.